TECP 700-700
Materiel Test Procedure 5-2-508
White Sands Missile Range

[illegible] March 1967

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

ACOUSTIC TEST PROCEDURES

1. OBJECTIVE

The objective of this procedure is to determine the effects of simulated or actual flight acoustics (high level noises) upon the missile skin, structure and components.

2. BACKGROUND

Accoustically transmitted vibration or noise is generated by the missile engine, mainly during the launch and boost phases of the flight. This noise has an energy level high enough to produce definite effects upon missile and its internal components. Noise of a lesser energy level is produced by aerodynamic turbulence during high velocity flight in the atmosphere.

This MTP assists the engineer conducting an acoustical laboratory test to determine the effects of high noise levels upon the missile skin, structure, and interior components. Such information is used to help determine the adequacy of equipment to meet specified requirements. Advantages and disadvantages of acoustical laboratory testing are discussed in Appendix E. Comparative information on sound, pressure, and spectrum levels and engine noise is contained in Appendix D.

3. REQUIRED EQUIPMENT

a. Recording of actual test environments
b. Applicable Acoustic Test Facility (see Appendix B)
c. Stroboscopic Light Source
d. Strain Gage
e. Deflection Gage
f. Accelerometer
g. Stress Coat
h. Microphone
i. Appropriate Filters
j. Tape Recorder
k. Mounting Bracket (for test specimen)
l. Temperature Chambers or shrouds (-85°F to 125°F)
m. Relative humidity indication
n. Barometer
o. Monitoring equipment

4. REFERENCES

A. Investigation of Flight Flutter Techniques, Final Report, Bureau of Aeronautics, U. S. Navy, MIT, Department of Aeronautical Engineering 1950

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J. Harris, C. M., (editor), Handbook of Noise Control, McGraw-Hill Book Co., Inc., New York, 1957
K. MTP 5-2-503, Restrained Firing Test Procedure
L. MTP 5-2-594, High Temperature Tests
M. MTP 5-2-583, Low Temperature Tests
N. MTP 5-2-604, Structural Data Analysis Methods
O. Military Standard, MIL-STD-810 (USAF), Environmental Test Methods for Aero-space and Ground Equipment, latest revision

5. SCOPE

5.1 SUMMARY

The test conduct is summarized as follows:

a. Reproduction Testing: Testing the specimen by using a recording of the actual environment or its simulated equivalent

b. Simulated Testing: Attaining equipment damage comparable to the damage sustained in flight.

c. Fatigue Testing: Determining the resistance of the specimen to below yield point strains.

d. Actual Operational Testing: Monitoring the specimen in its operational environment.

5.2 LIMITATIONS

The size of the test specimen to be tested is limited by the space available in the test chamber.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 General

a. Personnel involved in testing shall be familiar with the missile structure and components they are to test, and fully qualified in the use of associated test equipment and facilities.

b. Pertinent technical manuals, manufacturer's manuals, or such other material as is available shall be reviewed to make a proper selection of test equipment and accessories.

6.1.2 Instrumentation

During the conduct of the test, the physical characteristics and performance of the specimen shall be monitored in the following way:

a. Vibratory response of the specimen shall be measured by stroboscopic light, strain gage, deflection gage, accelerometer or stress coat (a thin brittle coat of lacquer or varnish).

b. The acoustic environment (see Appendix A) shall be monitored by microphones and appropriate filters to determine the intensity and spectrum of the applied sound pressure.

c. A tape recorder shall be used to record the acoustic spectra in use.

d. The specimen performance shall be monitored by using instrumentation normally associated with the specimen.

6.1.3 Test Conditions

Reproduction, simulated, and fatigue testing shall be conducted under the following conditions:

a. Microphones shall be located near the test specimen major surfaces.

b. Response measurement devices shall be located such that they do not appreciably effect the phenomenon being measured.

c. The stress coat for determining vibratory responses, shall be used selectively since it may alter the sound reflection qualities of the specimen and cause erroneous interpretations.

d. The sound pressure level (see Appendix C) shall be maintained at an intensity adequate to provide a comprehensive test of the missile and its components.

e. The frequency and amplitude distribution shall coincide with the time spectra of a normal flight.

f. The cycling rate or duration of the test shall correspond to field conditions.

Note: The conditions of c, d, and e shall be closely monitored to yield repeatable data. Ideally the conditions shall equal or exceed the acoustic intensity encountered during missile flight.

g. Relative to the sound application the specimen shall be oriented in one of the following ways:

1) Directory (perpendicular)
2) Coincidentally (grazing)
3) At an angular position
4) In a diffused field

h. The method of suspension shall depend upon:

1) The size of the specimen
2) The space available in the chamber
3) The results desired from the test

i. Items are required to conform to military and/or contractor specifications. Reference 4F includes all the necessary test parameters.

j. For a test in a reverberant room facility, the test item volume shall not exceed one-eighth of the interior volume. For a test in a free progressive wave tube, the test item area, projected on a plane perpendicular to the direction of propagation, shall not exceed one-third of the facility area.

6.1.4 Sound Field Survey

NOTE: Time required to conduct the sound field survey shall not be greater than one-third the planned test time, or, if this is not possible, the sound spectrum during the survey shall be approximately 15 decibels below the specified values.

Perform the following:

a. With the test item in place, the sound source shall be turned on to produce a spectrum approximately 10 decibels (see conditions specified in NOTE above) below the specified value.

b. Sound pressure level measurements shall be made and recorded to determine the degree of uniformity of the acoustic field.

c. A minimum of four microphones shall be used for sound survey and test in a reverberation room, and a minimum of two microphones shall be used for tests in a progressive wave or a standing wave facility.

6.2 TEST CONDUCT

6.2.1 Reproduction Testing

Reproduction testing is performed to determine the effect of the actual acoustic environment as reproduced from a recording, or its equivalent upon the specimen. The test shall be performed as follows:

a. Mount the specimen, in the appropriate test facility (see Appendices A and B), on a low frequency system or its own mounting bracket so that its orientation, relative to the sound application shall, as closely as possible, simulate flight conditions.

b. Instrument the specimen and test facility as required to meet the specific objectives of the test.

c. Activate/operate the test specimen when applicable.

d. Apply the required acoustic environment:

1) The time spectrum can be a playback of an actual environment recording or
2) The time spectrum can be adjusted to a power spectral density plot of the known environment using a random signal.

e. Ensure, by continuous monitoring with suitable michrophones and readout devices, that the acoustic environment meets the following specifications:

1) The sound pressure level (SPL) (see Appendix C) shall be maintained within three db of the required level.
2) The duration of testing shall be comparable with the time span of the in-flight acoustic environment.

f. Record the following:

1) Relative humidity
2) Ambient air temperature
3) Type of test facility used
4) Type, description, and orientation of the accustical transducers used, and a description of the auxiliary power and control systems
5) Time spectra parameters
6) Sound pressure levels for the overall SPL and 1/3 octave SPL to include:

   a) Reference level
   b) Deviations from reference level

7) Type, location and calibration of the monitoring instrumentation
8) Specimen response by means of continuous monitoring
9) Type of failure, (see Appendix F) when applicable and:

   a) Known history of the applied acoustic environment to specimen failure
   b) Modes of vibration for panel testing

Note: Caution shall be taken to determine that failure is not due to the effects of the acoustic environment upon the auxiliary equipment.

6.2.2 Simulated Testing

Simulated testing is performed to cause damage to the specimen which is equivalent to damage experienced in actual use.

Note: Simulated testing is performed when:

a) Actual acoustic environmental parameters are unavailable
b) Testing facilities are incapable of providing the necessary environmental conditions
c) Accelerated or decelerated testing is desired

a. Mount the specimen, where applicable, on a low frequency system or its own mounting bracket so that its orientation, relative to the sound application shall, as closely as possible, simulate flight conditions.

b. Instrument the specimen and test facility/area as required to monitor the acoustic environment and specimen response during the test.

c. Activate/operate the test specimen, when applicable.

d. Apply the simulated acoustic environment and record the information described in paragraph 6.2.1.f.

Note: Damage criteria for accelerated testing is related to fatigue failure which can be estimated by Miner's rule (see reference 4G). This rule depends upon a linear response system and is influenced by the unreliability of fatigue characteristics.

6.2.3 Fatigue Testing

Fatigue testing is performed to evaluate the environmental parameters required to induce fatigue or break the system. In addition, bending modes and the magnitudes of induced strain shall be ascertained.

a. Mount the test specimen in a plane wave, reverberant chamber, or progressive wave tube (see Appendix B) so that the proper direction of environment application is obtained.

Note: The specimen is usually mounted on a bracket.

b. Instrument the test facility to record the acoustic environment.

c. Instrument the test specimen with strain gauges, accelerometers and low deflection gauges.

d. Apply various acoustic environments and record the applicable information described in paragraph 6.2.1.f.

6.2.4 Extreme Temperature Tests

6.2.4.1 High Temperature Tests

Repeat paragraph 6.2.1, or 6.2.2, or 6.2.3, as applicable, using the procedures described in MTP 5-2-594.

6.2.4.2 Low Temperature Tests

Repeat paragraphs 6.2.1, or 6.2.2, or 6.2.3, as applicable, using the procedure described in MTP 5-2-583.

6.2.5 Actual Operational Testing

Tests shall be performed as described in MTP 5-2-503.

6.3 TEST DATA

6.3.1 Sound Field Survey

Record the following:

a. Spectrum of sound source in decibels below specified values.
b. Sound pressure levels in decibels.

6.3.2 Reproduction, Simulated and Fatigue Testing

a. Record the following:

1) Test being performed (Reproduction, Simulated or Fatigue)
2) Ambient temperature in degrees F
3) Relative Humidity in percentage
4) Type of test facility used (standing wave tube, Plane wave tube, etc).
5) Type, description and orientation of the acoustic transducers used.
6) Description of the auxiliary power and control systems used
7) Time spectra parameters, indicating frequencies, intensity (in db), and length of time applied
8) Overall sound pressure level and 1/3 octave SPL (in db) when applicable:

    a) Reference level
    b) Deviations from reference level

9) Type of:

    a) Specimen suspension
    b) Orientation (parallel, perpendicular or skew)

10) Type, location and orientation of monitoring instrumentation
11) Type of failure (intermittant, absolute, fatigue)

b. Retain tapes and oscillographs etc. of the following:

1) Acoustic environment
2) Specimen response

6.3.3 Actual Operation Testing

Data shall be recorded and collected as described in MTP 5-2-503.

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 General

All data shall be entered in the log book or folder for the test item under test. It is important that the test log is complete, accurate, and up-to-date as the log may be used for future test studies such as static tests, flight tests, restrained firing tests and acoustic tests.

Equipment evaluation usually is limited to comparing the actual test results to equipment specifications and the requirements imposed by the intended usage. The test results may also be compared with the results of previous acoustic tests, and actual flight or restrained firing tests that were conducted on the test item.

6.4.2 Reproduction, Simulated and Fatigue Testing

In the event of structural failures the acoustical data obtained shall be analyzed and presented as described in MTP 5-3-604.

6.4.3 Actual Operation Testing

In the event of structural failures, the data obtained by performing restrained firing tests (structural, shock, vibration and acoustical) shall be analyzed and presented as described in MTP 5-2-604.

APPENDIX A

THE ACOUSTIC ENVIRONMENT

The worst noise environment for the missile occurs during launch conditions. At that time, the missile has no forward velocity and is near sound reflecting surfaces such as the earth, buildings, etc. Sound pressure levels (SPL) as high as 182 decibels (db) at a reference of 0.0002 dynes per square centimeter have been recorded at the skin of a missile, which may extend to 208 db in the case of space vehicles having at least 1.5 million pounds of thrust. The type of propulsion system and the physical characteristics of the vehicle have the most influence upon the acoustic environment. During the course of the missile flight, the direct and reflected noise generated by the propulsion equipment is replaced by aerodynamically generated (boundary layer) noise, with an intensity level as a function of velocity. The number of variable factors introduced by time, velocity, and distance complicate an accurate prediction of the acoustic environment for any particular vehicle.

Acoustical and vibrational environments are similar. The main difference is that a vibration environment requires a physical or mechanical linkage between the forcing system and the response system, while the acoustic environment is transmitted through the surrounding fluid by sound waves. In general, only an acoustic environment above the 130db sound pressure level warrants consideration in missiles.

Lightweight structures, thin panels, and electronic and hydraulic components are particularly subject to the effects of an acoustic environment.

APPENDIX B

ACOUSTIC TEST FACILITIES AND EQUIPMENT

Standing Wave Tube

The standing wave tube generally is used in the measurement of the coefficient of absorption of materials, in indicative type tests, or in the fatigue testing of items small enough to fit within the tube.

The standing wave tube shown in Figure B-1 has a length of six feet and a diameter of 2.4 inches. The acoustical transducers shall be mounted at one end. The other end of the tube can be located an integral number of wave lengths from the transducer to establish standing waves. The test specimen shall be mounted on the adjustable end and positioned to receive maximum sound pressure. The tube achieves high SPL with a relatively low power input at low frequencies where the wavelength (λ) is more than twice the diameter of the tube. Further information is contained in Reference 4G.

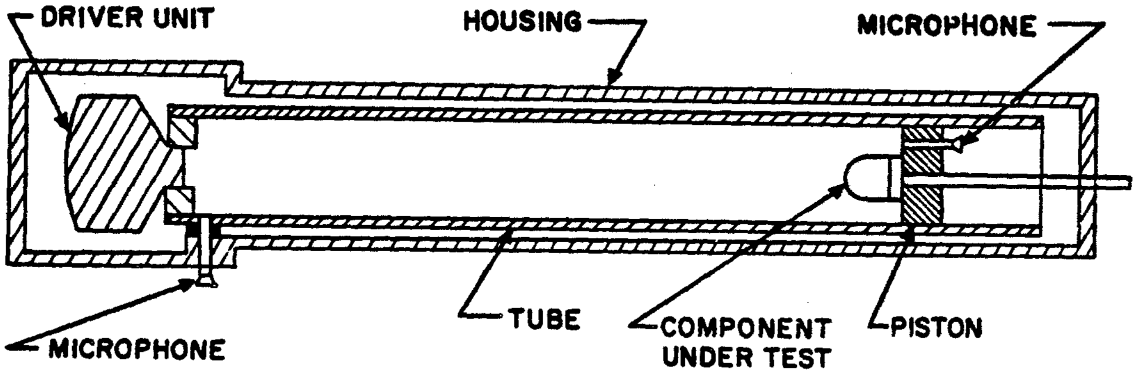


FIGURE B-1 STANDING WAVE TUBE

Plane Wave Tube

The plane wave tube is adapted to the testing components smaller than the diameter of the tube. When the specimen occupies less than half the diameter of the tube, an SPL of 145 to 180 can be attained.

Tube diameters range from two to eight inches, necessitating low frequencies where λ is more than twice the tube diameter. The tube requires a highly absorbent termination on a match to the free field to prevent reflection. Further information is contained in Reference 4H.

Progressive Wave Tube

Unlike the plane wave tube, the progressive wave tube is not as well matched and therefore not particularly limited by the ratio of wavelength to tube diameter. A specimen measuring one by one by three feet may be tested at an SPL of 164 db at low frequency and 154 db at high frequency.

The system consists of acoustical transducers at one end of the tube

The system consists of acoustical transducers at one end of the tube and a highly absorbent termination at the other end, as shown in Figure B-2. Further information is available in Reference 4H.

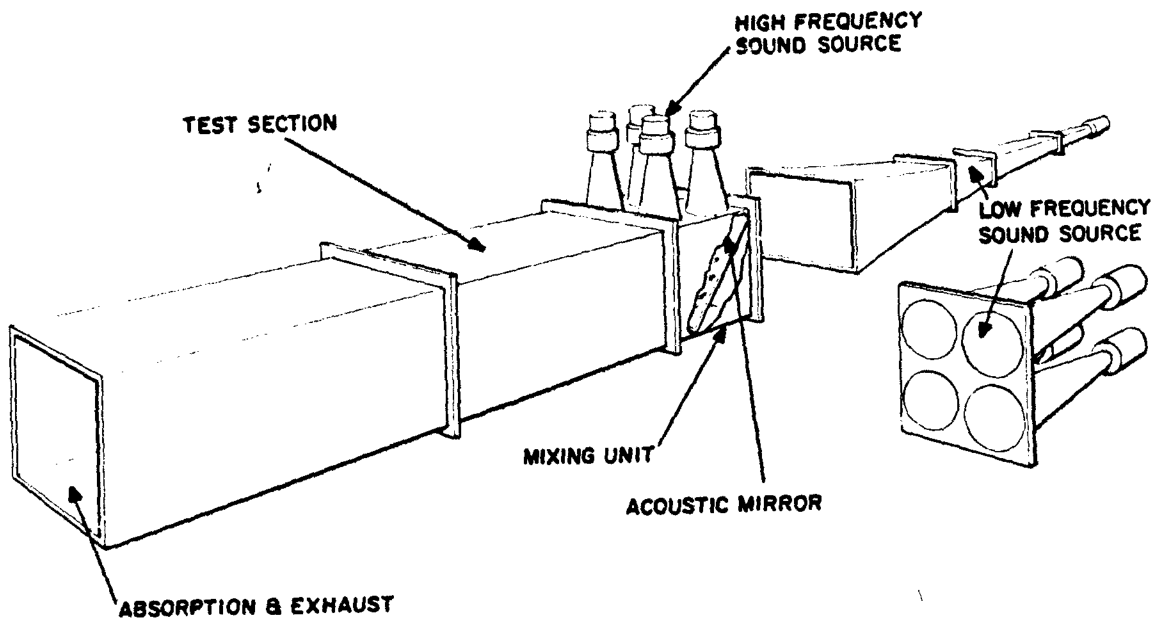


FIGURE B-2 PROGRESSIVE WAVE TUBE

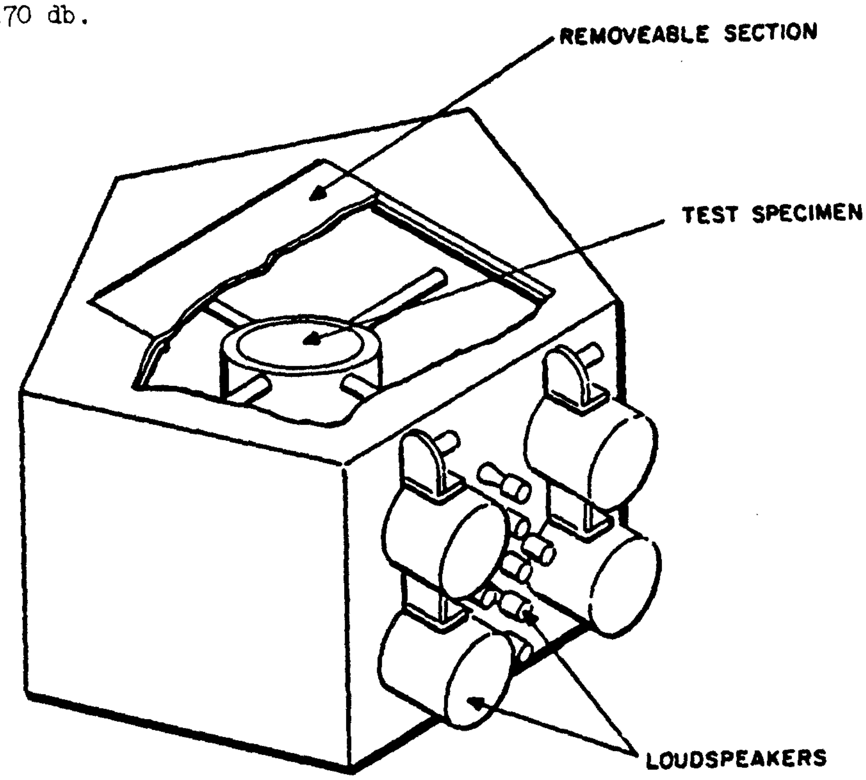
Reverberent Chamber

The reverberent chamber is large in comparison with the other systems. It is built with highly reflective interior surfaces, none of which are parallel. Baffles are arranged in the acute corners to deter the formation of standing waves. The chamber is designed to establish a diffused field in the test area at least half a wavelength from all surfaces. Since the chamber supplies power only to the surfaces of the item under test, it is more efficient than progressive or plane wave systems. Nominal test volumes are about 0.1 of the total chamber volume. A typical value of SPL is a homogenous diffused field within 3db at 150 db. The general configuration of a reverberant chamber is shown in Figure B-3. Further information is available in Reference 4H.

NOTE: A sound pressure level of 130 db represents the threshold of pain. Personnel exposed to this environment may suffer physical injury and/or impairment of senses and body functions.

Pistonphone

A pistonphone is a sealed chamber in which a piston or a set of synchronized pistons are installed in the walls to produce sound pressure at low frequencies. It operates at frequencies from 0.01 to 50 cycles per second (cps), at an intensity depending upon piston area and length of piston travel. Sound pressure levels of 162 db have been attained in chambers of 10 to 200 cubic feet of volume, while in chambers of less than one cubic foot the SPL may reach 170 db.



B-3 REVERBERANT CHAMBER

Acoustic Transducers

Several of the more commonly used acoustical transducers and their relative efficiencies are indicated in Figure B-4.

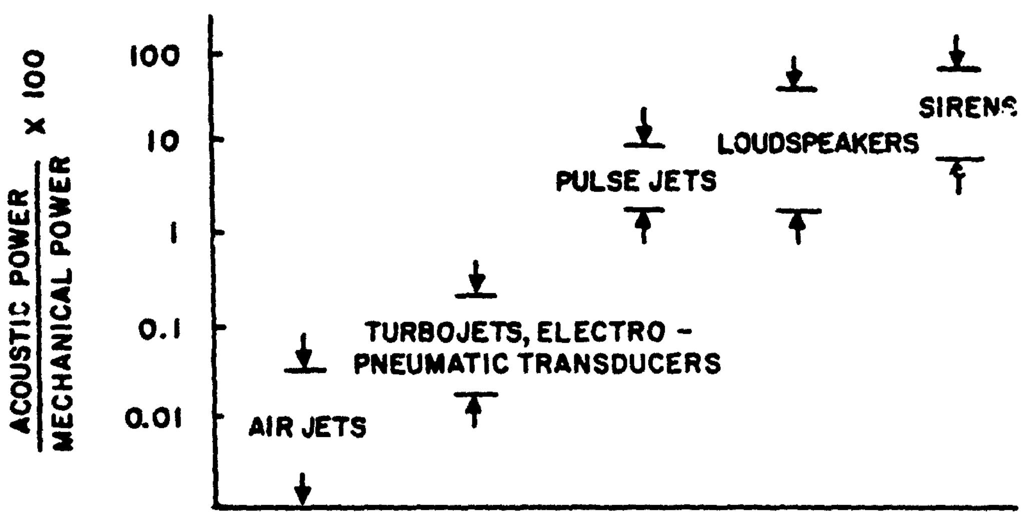


FIGURE B-4 RELATIVE EFFICIENCY OF NOISE SOURCES

APPENDIX C

SOUND CHARACTERISTICS

The sound power level (PWL) usually is expressed in db at a reference of 10^{-12} watts. PWL = 10 $\log_{10} \frac{W}{Wo}$ db, where W is watts and Wo is a reference power in watts (10^{-12} watts). The letter p generally is appended to db indicate that the reference power is one picowatt (10^{-12} watts). The reference The reference power of 10^{-13} watts used in some publications may be converted to 10^{-12} watts by subtracting ten db from the PWL. (1)

The sound pressure level (SPL) is expressed in db at a reference of 0.0002 dynes per square centimeter. SPL = 20 $\log_{10} \frac{p}{po}$ db, where po is the reference pressure level (0.0002 dynes/cm^2) and p is the given sound pressure. The reference pressure fixes the zero db point on a scale of sound pressure level. The chart shown in Figure C-1 may be used to convert SPL in db into root mean squared pressure in pounds per square inch.

The speed of sound in air (C) is expressed in feet per second. $C = \frac{1.4\ Po^{\frac{1}{2}}}{po}$ where Po is the atmospheric pressure in pounds per square foot (3)
and po is the mass density of the air in $\frac{lb - sec^2}{ft^4}$. Since the speed of sound depends only upon the absolute temperature of the air, $C = 49.03R^{\frac{1}{2}}$ feet per (1)
second, where R is the temperature in degrees Rankin (459.7 plus the temperature in degrees Fahrenheit).

If a sound source is known to be nondirectional and is located in free space, the relationship between SPL and PWL is as follows:

$$SPL = PWL + 10 \log_{10} [(\frac{F^o + 460}{527})^{\frac{1}{2}} \frac{30}{B}] - 20 \log_{10} r - 10.5 \text{ db}$$

where F^o is the temperature in degress Fahrenheit, B is the atmospheric pressure in inches of mercury, and r is the distance in feet from the noise source. When the source is directional, the amount b which the directional sound pressure level (SPL_d) in a specified direction exceeds the level of the mean squared sound pressure (SPLav) at the same distance. An averaged overall direction is the directional gain (G). G = SPL_d- SPLav db. By substitution, (6)
$SPL = PWL + G + 10 \log_{10} [(\frac{F^o + 460}{527})^{\frac{1}{2}} \frac{30}{B}] - 20 \log_{10} r - 10.5$ db. At 67 (7)
degrees Fahrenheit and 30 inches of mercury, $10 \log_{10} [(\frac{F^o + 460}{527})^{\frac{1}{2}} \frac{30}{B}] = 0$.
If directional effects are not considered, a rough calculation is:

$$SPL = PWL - 20 \log_{10} r = 10.5 \text{ db.} \quad (8)$$

The equations apply to sound spreading in a sphere. If the sound is restricted to a hemisphere, as at missile launch, for a given PWL the SPL increases three db.

In a free field, sound diverges spherically, therefore, the SPL

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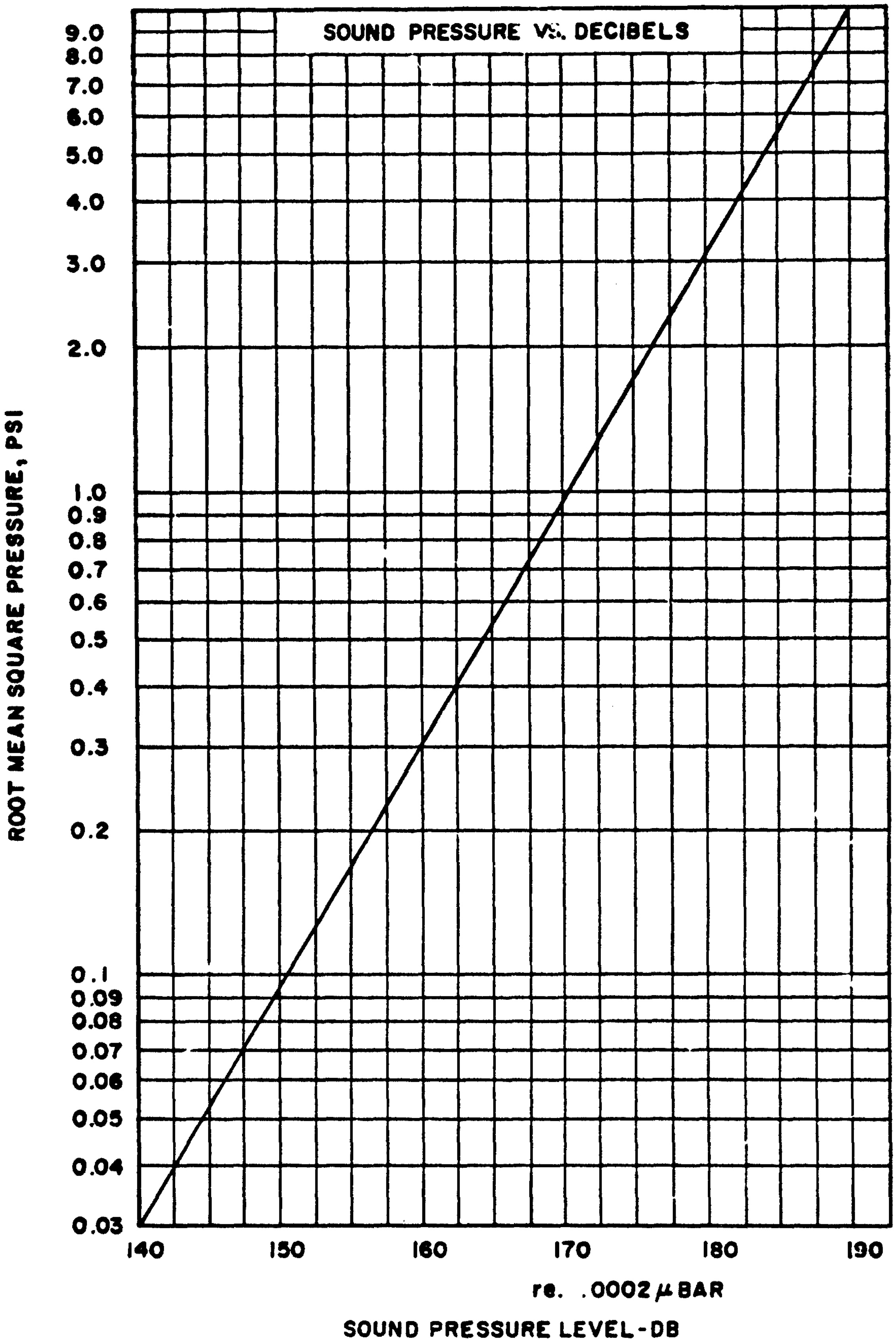


FIGURE C-1 SPL TO ROOT MEAN SQUARED PRESSURE varies inversely as the distance from the point source. The SPL at a given distance rx is

$$SPLx = 20 \log \frac{Px}{0.0002} \text{ db}$$

so the SPL at any distance r is

$$SPL = SPLx - 20 \log_{10} \frac{r}{rx} \text{ db} \tag{9}$$

This is the logarithmic form of the inverse square law which states that if r is doubled, the SPL drops six db, and if r is halved, the SPL increases six db.

APPENDIX D

COMPARATIVE INFORMATION

a. Relative Sound Levels

Typical sound levels for different noise sources are shown in Figures D-1 and D-2. Acoustic measurements collected from small missiles are shown in Figures D-3, and D-4 and D-5. Missile A is a short range, supersonically launched air to air missile. Its rocket motor may be either liquid fueled or solid fueled, and has a running time of only a few seconds. Missile B is a short range air to surface missile similar to Missile A, except that it is launched subsonically. Missile C is a long range combination rocket-ramjet target missile operating at speeds approaching Mach three. The data were collected from restrained firings of the missiles.

b. Combining Sound Pressure Levels

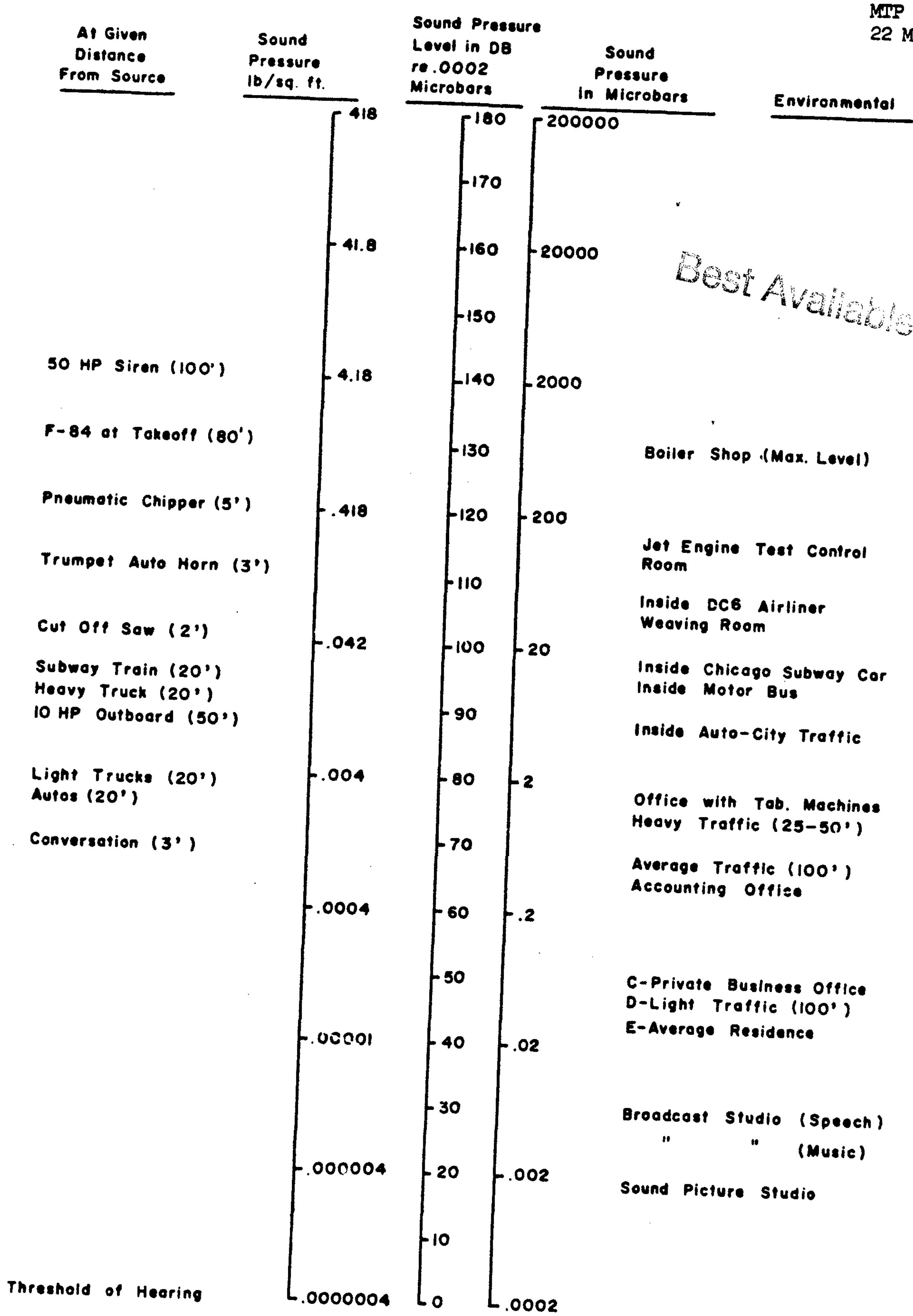
A number of possible situations require combining several quantities expressed in decibels. For example, it may be necessary to predict the combined noise level resulting from the simultaneous firings of two or more missiles from adjacent launchers when the noise level of one firing is known. Given the SPL's in different frequency bands, computation of the overall SPL may be required. In these situations, the decibel quantities should not be added directly. They must be converted to relative powers, added or subtracted, then reconverted to decibels. A chart used in making this calculation is shown in Figure D-6. The decibel level to be added is rounded off to the nearest integer.

c. Plotting Spectrum Levels

Data obtained with analyzers of different bandwidths may be compared by reducing all observations to that which would have been obtained with a common bandwidth of one cycle per second. By using Figure D-7, this may be accomplished graphically by two different methods. The first method depends upon knowledge of the actual bandwidth in cycles per second. Using a pass band of twenty cycles per second, for example, the bandwidth shows the conversion from the observed twenty cycles per second yields the spectrum level for all frequencies. The second method of obtaining the spectrum level depends upon the use of a proportional band, such as an octave, and knowledge of the center frequency of the band. Suppose the problem is to compute the spectrum level at 1000 cycles per second, given the half-octave band level of 160 db. The conversion for a half-octave band of 1000 cycles per second is shown as 25.4 db; therefore, the computed spectrum level in this half-octave band is about 160 - 25, or 135 db.

Given data plotted as a spectrum level, the levels can be combined to obtain an approximate overall SPL in three steps, as follows:

1. The spectrum is arbitrarily approximated by a number of contiguous rectangular blocks whose tops are at the spectrum level of the actual noise at the center of the block (on a logarithmic frequency scale). This is equivalent to using the spectrum level at the geometric center frequency of the band.



D-1 TYPICAL SOUND LEVELS

Sound Power In Watts	Sound Power Level in DB Re 10-13 Watts	Source
10000000	200	Rocket Engine 1000000 lb. Thrust
1000000	190	
100000	180	Turbojet Engine W/Afterburner
10000	170	Turbojet Engine 7000 lb. Thrust
1000	160	4 Engine Prop Airliner
100	150	75 Piece Orchestra
100	140	Small Aircraft Engine
1	130	Large Chipping Hammer Piano
.1	120	Tuba Blaring Radio Centrifugal Fan 13000 CFM
.01	110	Auto on Highway
.001	100	Vaneaxial Vent Fan 1500 CFM Voice, Shouting
.0001	90	
.00001	80	Voice, Conversation
.000001	70	
.0000001	60	
.00000001	50	
.000000001	40	Voice, Very Soft Whisper

D-2 TYPICAL POWER LEVELS

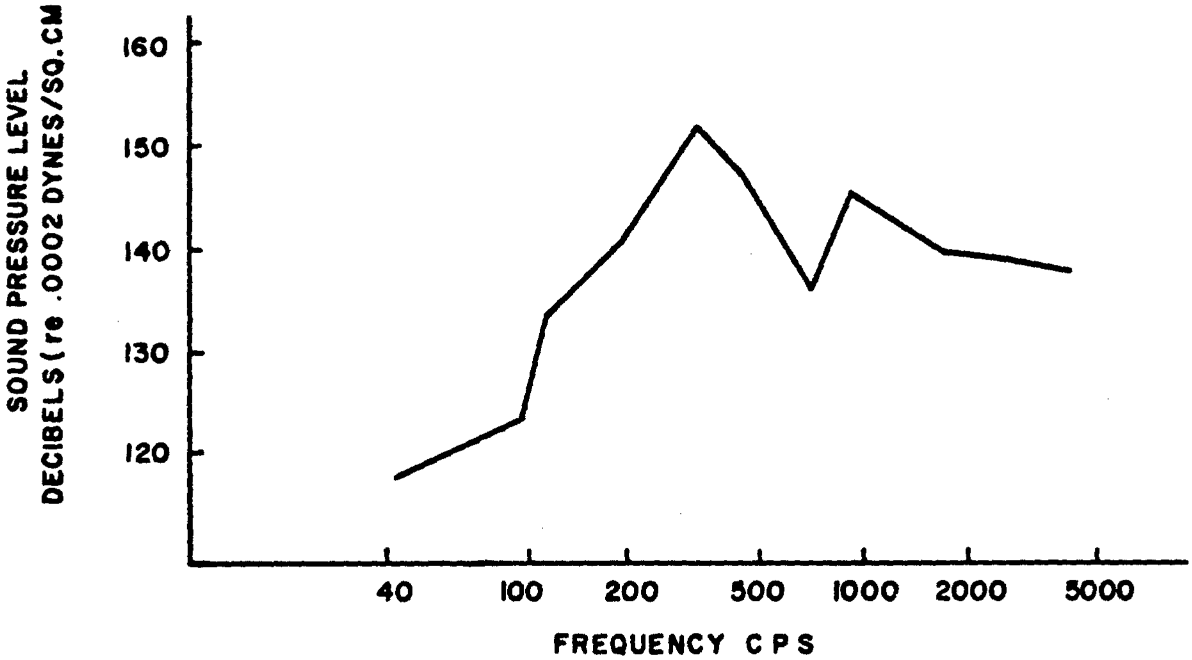


FIGURE D-3 MISSILE A, MICROPHONE IN ELECTRONIC COMPARTMENT

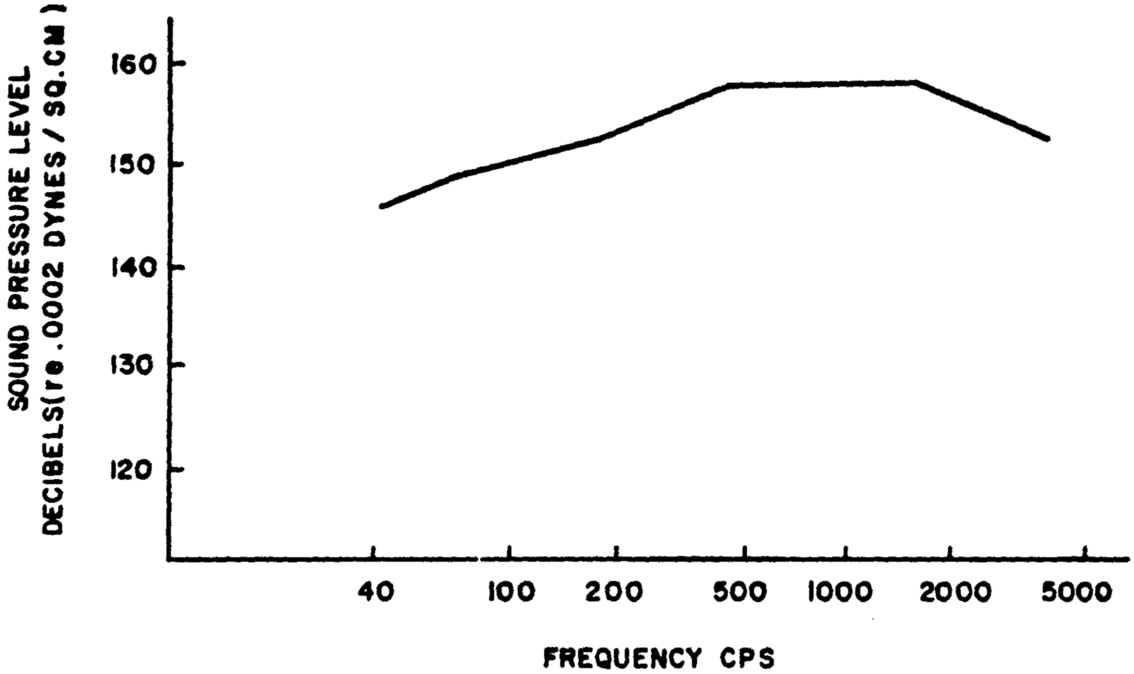


FIGURE D-4A MISSILE B, EXTERIOR MICROPHONE

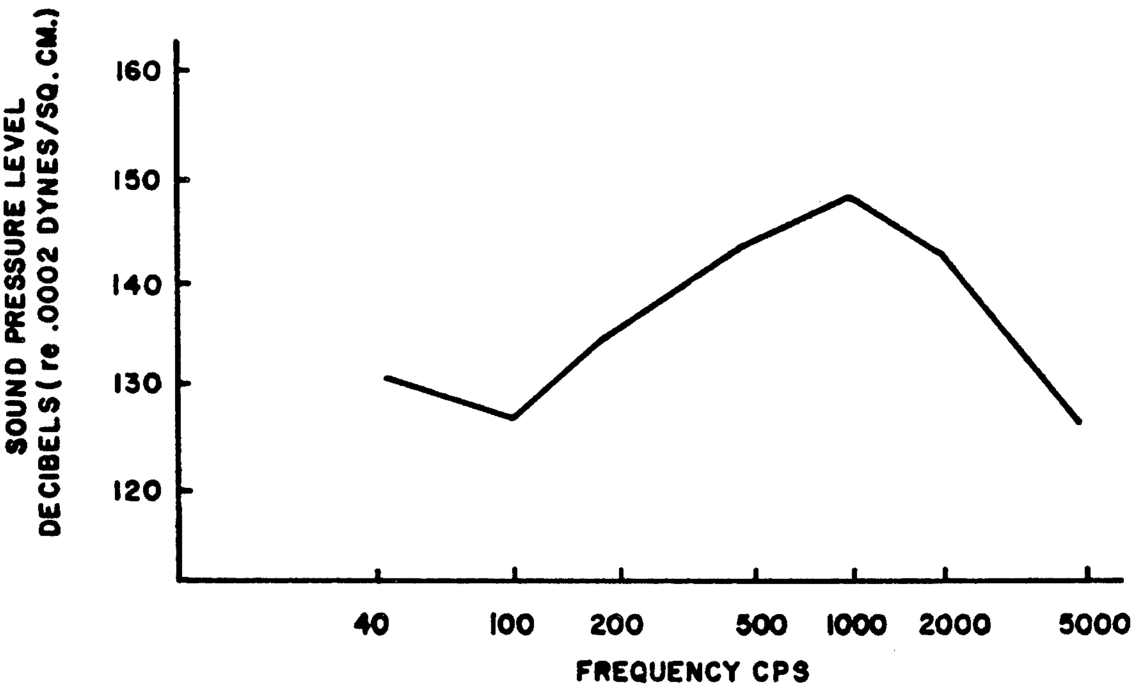


FIGURE D-4B MISSILE B, INTERIOR MICROPHONE GUIDANCE COMPARTMENT

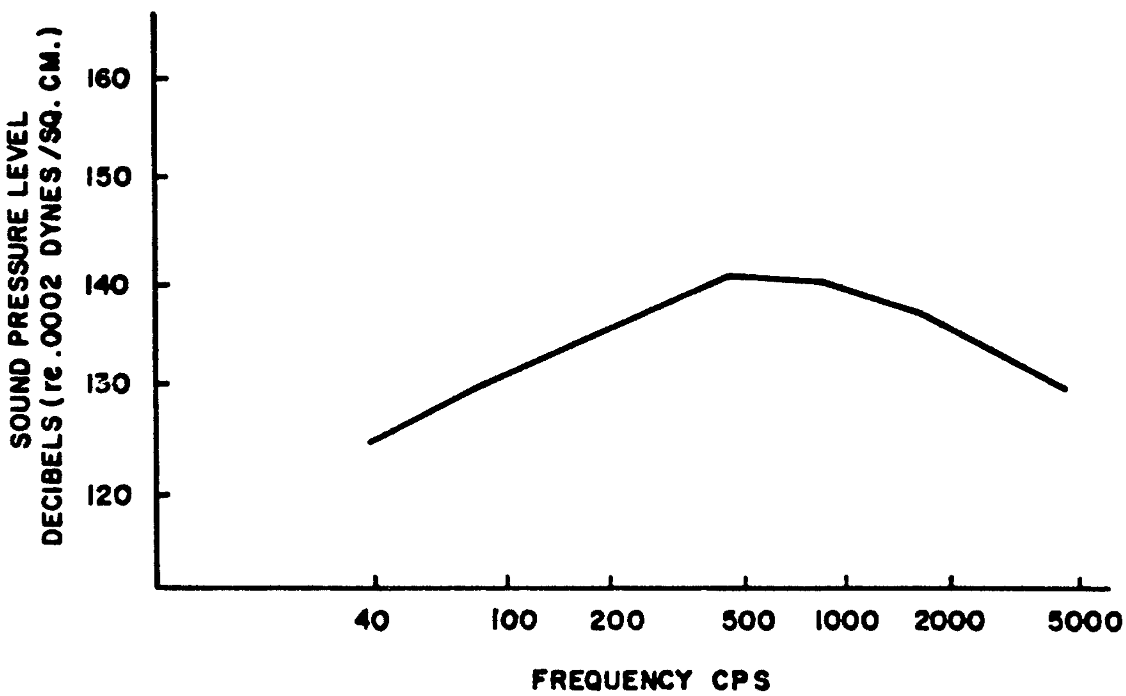


FIGURE D-5 MISSILE C, BOOSTER TEST

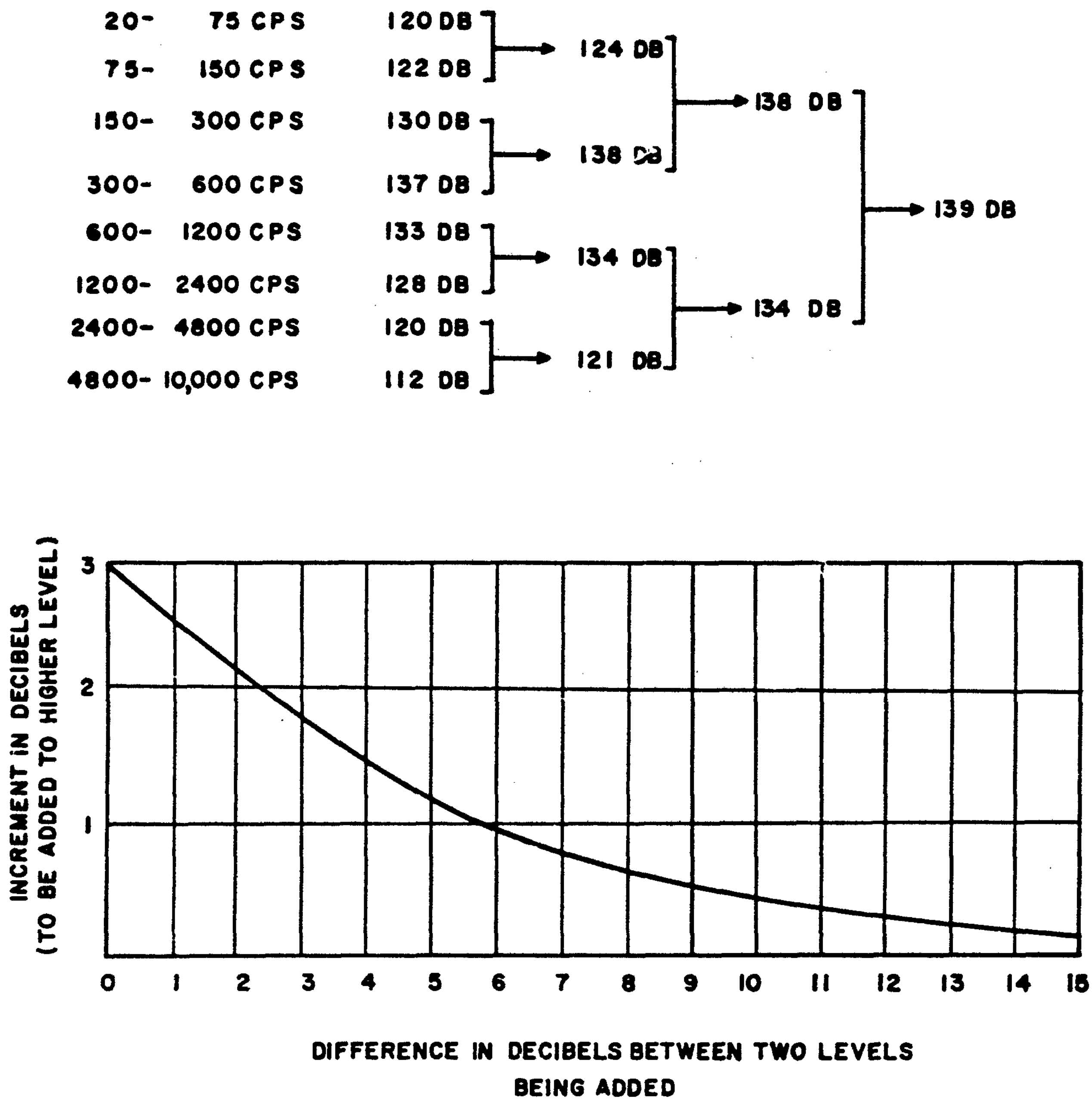


FIGURE D-6 COMBINING NOISE LEVELS

2. The extremes of each of the rectangular blocks then represents a frequency band pass. The conversion factor provided by Figure D-7 is added to the spectrum level to obtain the SPL corresponding to the frequency band.

3. The SPL's in each frequency band are combined to obtain the overall level as explained in paragraph b.

d. Sources of Rocket Engine Noises

The most important source of noise is the mixing of the high velocity rocket outlet stream with the relatively quiescent atmosphere. The noise level occasionally is increased by rough burning and combustion noise as much as 15 db. In general, solid and liquid fueled rockets produce approximately the same noise level for the same thrust and nozzle. The turbulent mixing effect around a rocket engine is shown in Figure D-8. The high frequency noises (above approximately 800 cycles per second) are radiated from a point source downstream within ten diameters of the rocket nozzle. The source of the low frequency noises (above approximately 800 cycles per second) are radiated from a point source downstream within ten diameters of the rocket nozzle. The source of the low frequency noises usually is from 5 to 20 diameters from the nozzle. It should be noted that the noise emitted by the rocket engine is directional, with an SPL, gain of five to six db between 110 and 130 degrees from the nozzle location on the motor axis.

The observations in this paragraph were derived from extensive measurements of conventional rocket engines. Since little physical reasoning is involved, the results are purely empirical; therefore, they are subject to the limitations imposed by derivation of particular results from general data.

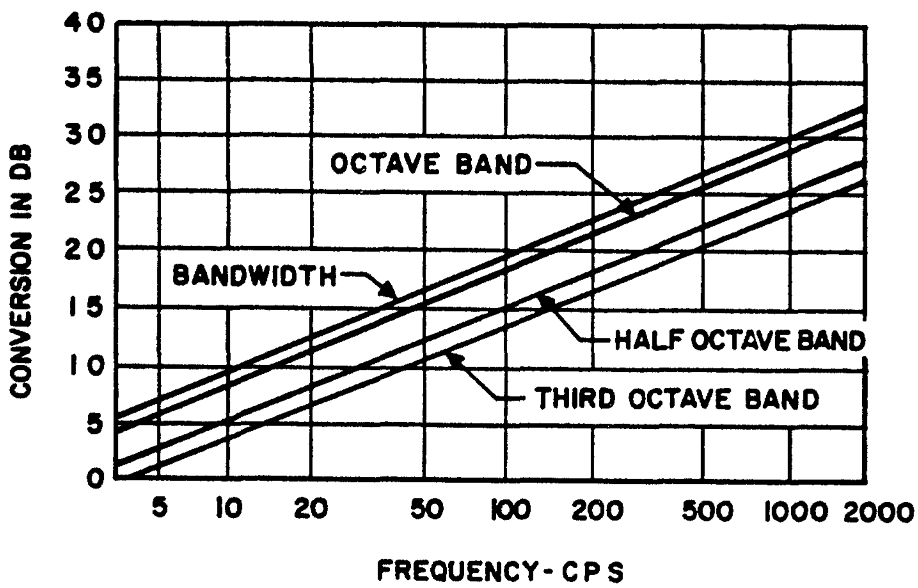


FIGURE D-7 CONVERSION FACTOR IN DECIBELS

e. Prediction of Rocket Engine Noise

Using empirical data, the acoustical power level output (PWL) emitted by a rocket engine can be estimated as follows:

$$PWL = (68 + 13.5 \log_{10} Wm) \text{ dbp re } 10^{-12} \text{ watt} \tag{10}$$

where:

$Wm = 0.676\, w \dfrac{V^2}{g} = .676\, t^2 \dfrac{g}{w} = 2177 \dfrac{t^2}{w}$ in watts

w = the total weight flow of primary air and fuel through the rocket engine in pounds per second.

$V = \dfrac{tg}{w}$ = the effective exit velocity in feet per second calculated from the engine thrust t in pounds

g = the gravitational constant, 32.2 feet per second squared.

This equation was derived from engines producing up to 150,000 pounds of thrust. In general, data have revealed that rocket engines have an acoustic power output which is five to ten db higher than turbojet engines of equal thrust.

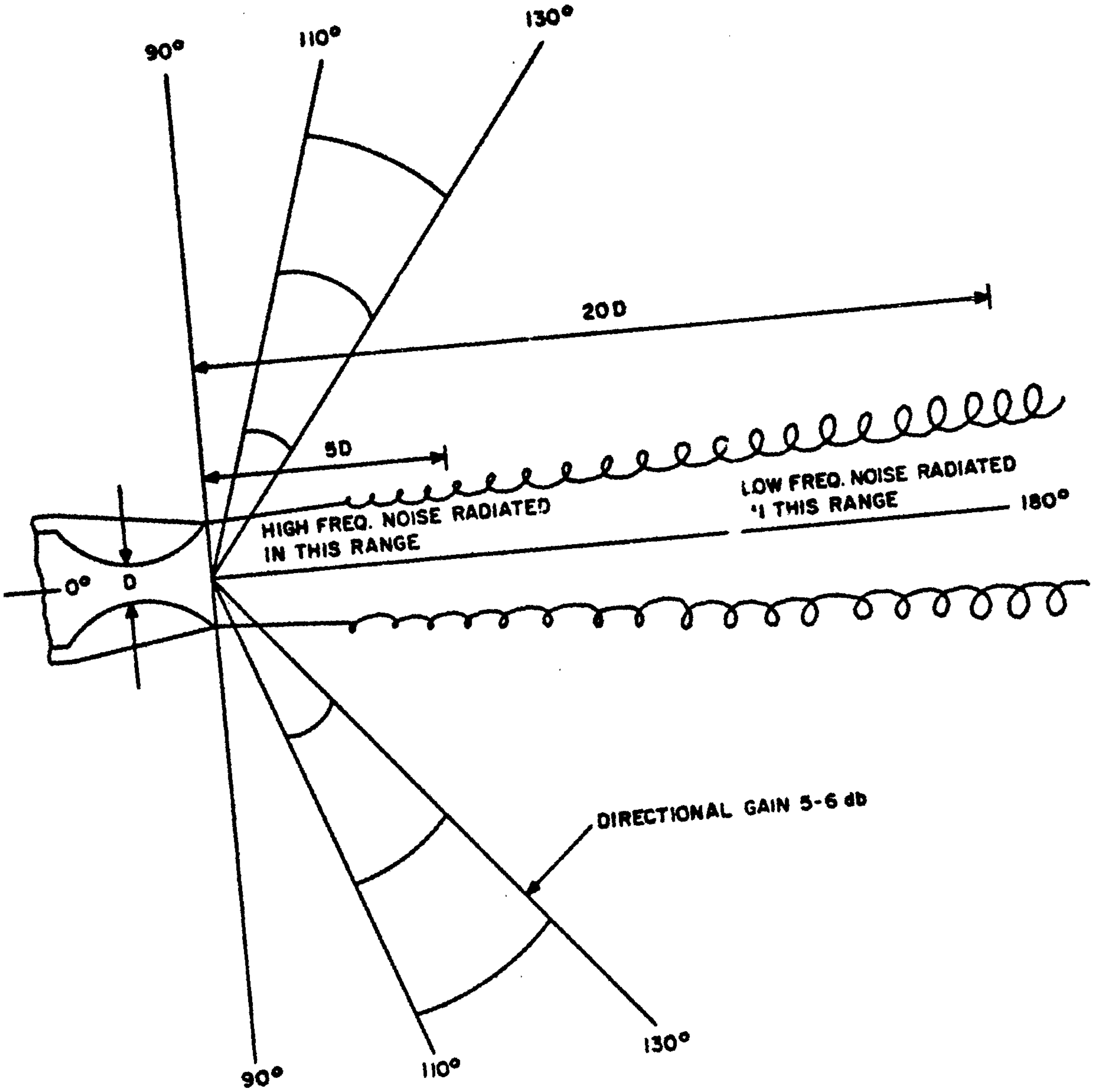
Equation (7) may be used to estimate the overall SPL, in the far field (usually considered to be 50 feet from the source) by considering the directional gain, calculated PWL, location of the source, and atmospheric conditions. In the near field, the noise is radiated about the structure and the particle movement of the air is random. As a general rule, in the near field the SPL impinging on a structure is from three to ten db higher than the field value.

In recent years, models with small air jets have been used to generate predictions of the near field acoustic environments. Scaling laws have been developed to translate the measurements from the model into predictions on the full size missile. If model data are not available, a rough estimate of the overall SPL may be made by using equation (7) plus three to six db.

The prediction methods outlined so far have been concerned with estimates of the SPL in frequency range of 20 to 10,000 cycles per second. Frequency spectra for noise impinging upon the structure, and for noise transmitted through the structure into the guidance package, are shown in Figure D-3, D-4 and D-5. Notice that the lower frequencies pass through the structure with little reduction, while the higher frequencies are attenuated from 10 to 30 db.

The above prediction methods are valid only while the missile is stationary. The noise level on the surface of the missile decreases rapidly as the missile velocity increases. At about Mach one, the rocket engine noise has no effect, since the missile "outruns" it. However, as the velocity of the missile increases, boundry layer or aerodynamic noise assumes more importance. It is caused by the mixing of the turbulent air next to the missile exterior with the relatively quiescent atmosphere. The frequency spectra for boundry layer noise have greater SPL's at the higher frequencies, which are attenuated by the missile structure and have little destructive effect. An emirical equation has been developed from the limited amount of boundary layer noise data collected, which relates the overall SPL with the dynamic pressure as follows:

$$SPL = 82 + 20 \log_{10} q \left(\text{db re } 0.0002 \frac{\text{dynes}}{\text{cm}^2}\right) \tag{11}$$



D-8 ROCKET ENGINE NOISE SOURCE CHARACTERISTICS where: q = dynamic pressure in pounds per square foot

Data have been collected for dynamic pressures ranging from 21 to 1000 pounds per square foot. At $q = 1000$, the overall SPL is approximately 142 db. Equation (11) yields the overall SPL on the exterior surface of the missile.

APPENDIX E

ADVANTAGES AND DISADVANTAGES OF ACOUSTICAL LABORATORY TESTING

a. Laboratory Test Advantages

Several of the advantages of laboratory tests, as opposed to flight tests, are as follows:

1. Laboratory tests cost less.
2. Laboratory tests are not as hazardous.
3. The environmental conditions can be duplicated with reasonable accuracy for comparative tests.
4. The test facilities can be located near to the instrumentation and recording equipment.

b. Laboratory Test Disadvantages

Some of the difficulties encountered in acoustical testing are as follows:

1. Measurement and prediction of the environment of the near field is uncertain.
2. It is difficult to calculate the bending modes of plates, panels, etc. caused by the acoustical environment.
3. The factors in 2 above hinder the location of optimum monitoring points on the specimen.
4. The test facilities often are not capable of producing the required environment.
5. It is difficult to translate measured service environments into reasonable laboratory tests.

APPENDIX F

TYPES OF FAILURE

a. Intermittant Failure

Failure of electrical and hydraulic equipment during the acoustic test with a return to normal operation upon withdrawal of the acoustic environment.

Caution should be taken to determine that failure is not due to the effects of the acoustic environment upon the auxiliary equipment.

b. Absolute Failure

Failure during and after the application of the acoustic environment without return to normal operation.

Caution should be taken to determine that failure is not due to the effects of the acoustic environment upon the auxiliary equipment.

c. Fatigue Failure or Breakage

Physical deterioration or breakage of the structural material.